United States Patent [19]

Stiller et al.

[11] **Patent Number: 4,641,611**

[45] **Date of Patent: Feb. 10, 1987**

[54] **OSCILLATORY MOTION APPARATUS**

[75] Inventors: **Alfred H. Stiller; James E. Smith,** both of Morgantown, W. Va.

[73] Assignee: **West Virginia University,** Morgantown, W. Va.

[21] Appl. No.: **706,153**

[22] Filed: **Feb. 27, 1985**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 628,248, Jul. 6, 1984, abandoned.

[51] **Int. Cl.**[4] **F02B 75/22**

[52] **U.S. Cl.** ..... **123/55 A;** 123/56 AC; 123/193 C

[58] **Field of Search** ..... 123/197 R, 197 A, 197 AB, 123/55 R, 55 A, 55 AA, 56 R, 56 AC

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,421,164	5/1947	Senkowski	123/55 A
2,790,431	4/1957	Gassmann	123/90.31
3,277,743	10/1966	Kell	123/55 A
3,329,134	7/1967	Llewellyn	123/197 A
3,831,565	8/1974	Avery	123/55 A
4,419,971	12/1983	Nakamura et al.	123/193 C
4,485,768	12/1984	Heniges	123/48 B

FOREIGN PATENT DOCUMENTS

251269	3/1927	United Kingdom	123/56 AC
2038984	7/1983	United Kingdom .	

OTHER PUBLICATIONS

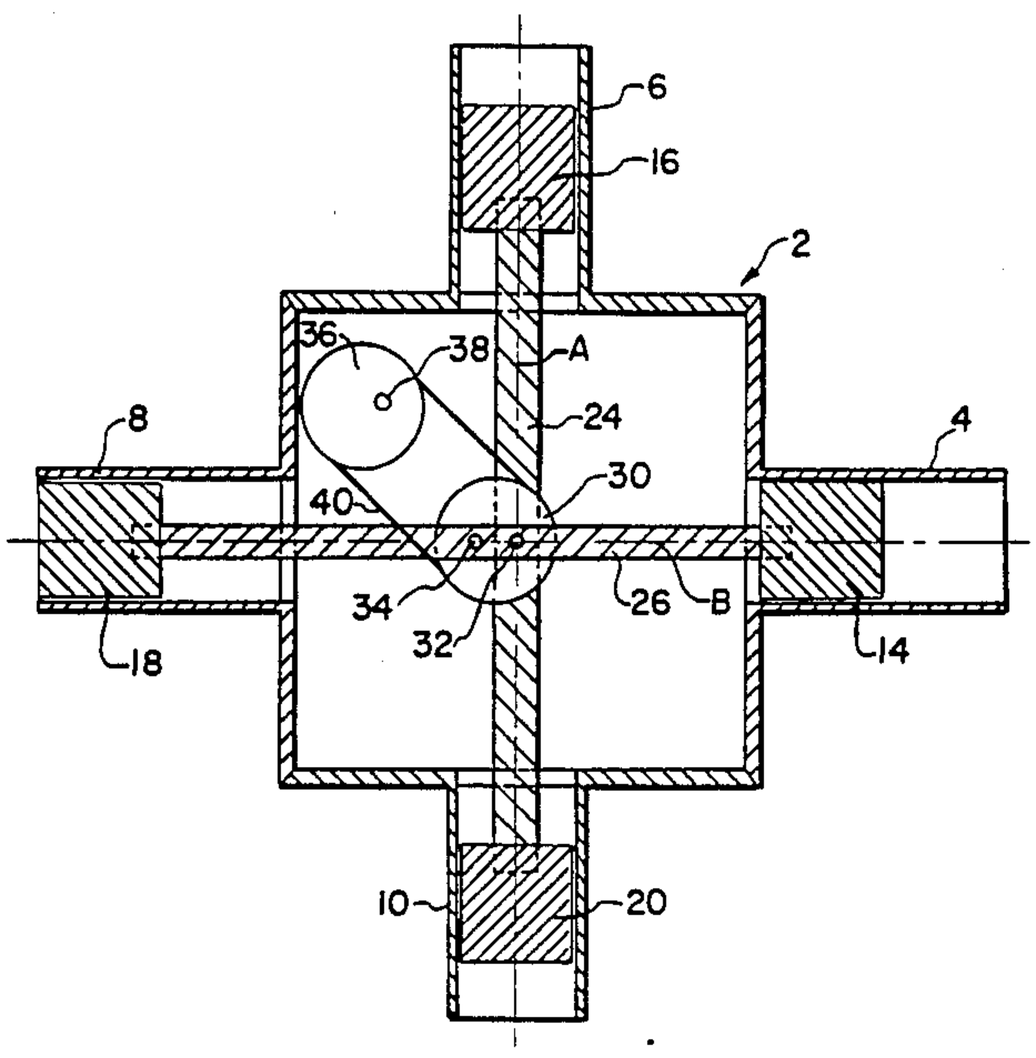
Baker et al; An Eccentric Crank Mechanism; Instn. Mech. Engrs.-Mechanisms; 1/1973; Paper No. 4; pp. 20–29.

Primary Examiner—Craig R. Feinberg
Attorney, Agent, or Firm—Arnold B. Silverman

[57] **ABSTRACT**

Oscillatory motion apparatus has a first reciprocating rod oriented generally perpendicularly with respect to a second reciprocating rod. A first trammel gear is pivotally secured to the first and second rods. Reciprocation of the rods produces responsive rotation of the trammel gear. An output gear may be rotated responsive to rotation of the trammel gear. The invention may be embodied in an engine block and two or more pairs of opposed cylinders each containing pistons adapted for reciprocation therein is provided. The rods, which may be connecting rods, connect pairs of opposed pistons. The connecting rods are preferably oriented generally perpendicularly with respect to each other. The connecting rods are rotatably connected to the trammel gear. Reciprocation of the pistons results in rotation of the trammel gear which is operatively associated with an output gear to produce rotary output. In one embodiment a bifurcated connecting rod permits two trammel gears to be employed with corresponding use of two output gears. In another embodiment, a planetary arrangement is provided. The engine is compact, lightweight and has a very high horsepower to weight ratio.

15 Claims, 18 Drawing Figures



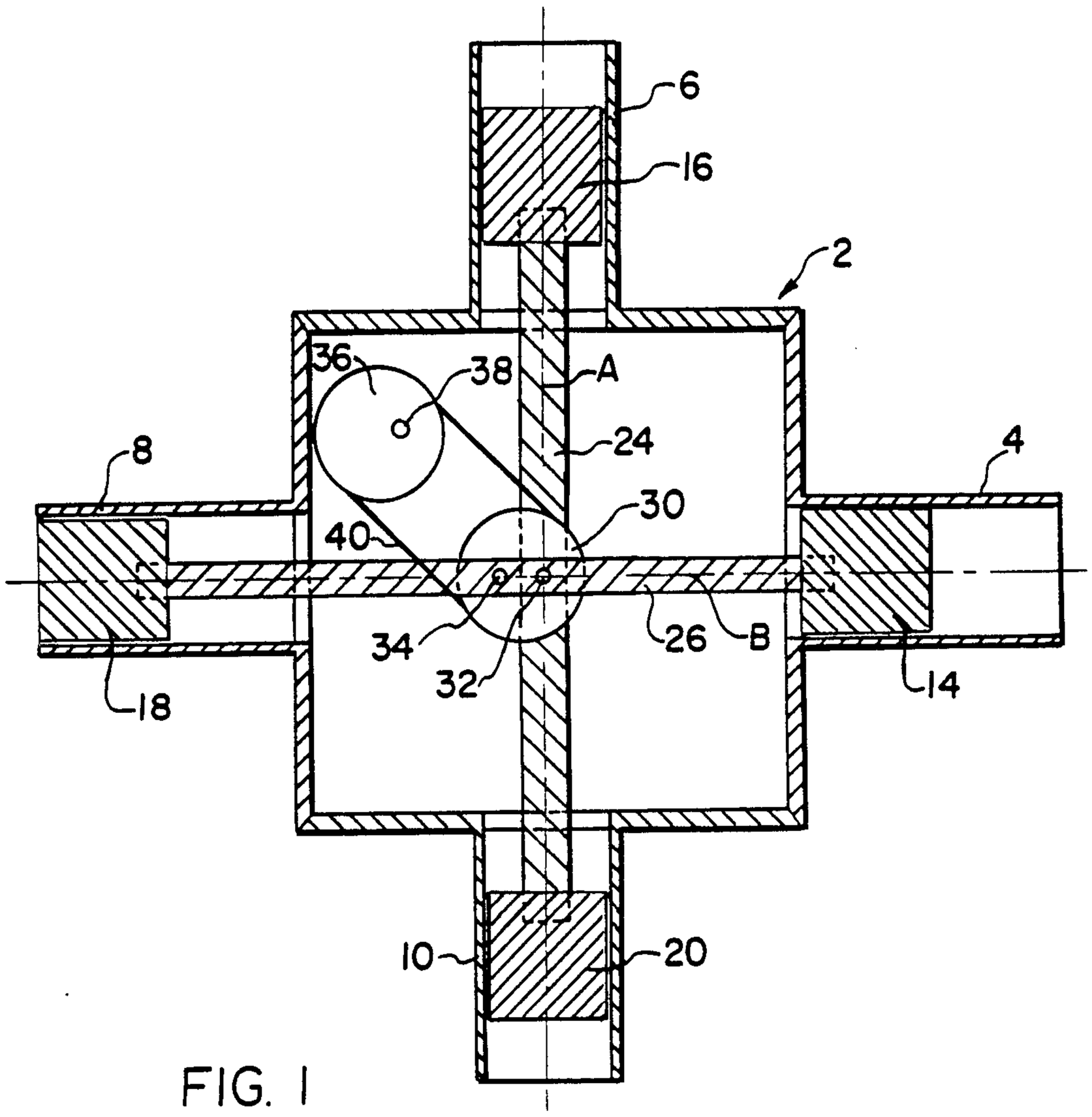


FIG. 1

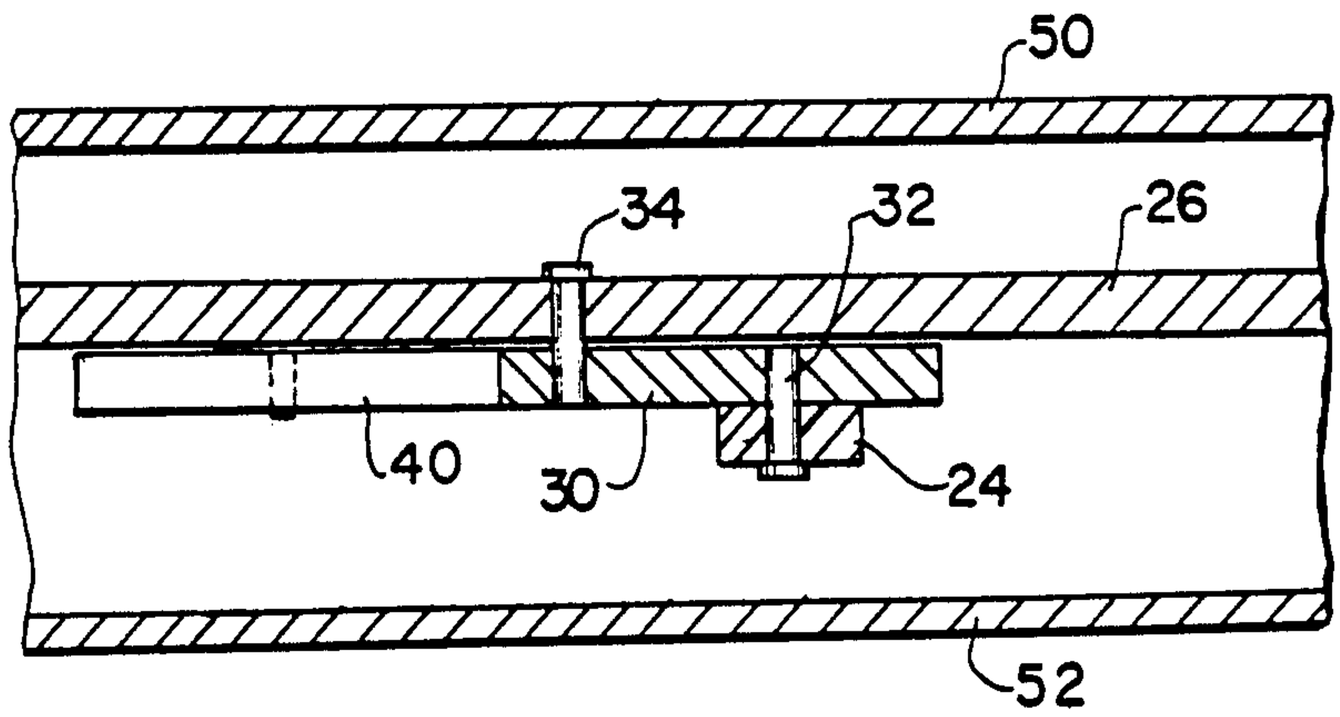


FIG. 2

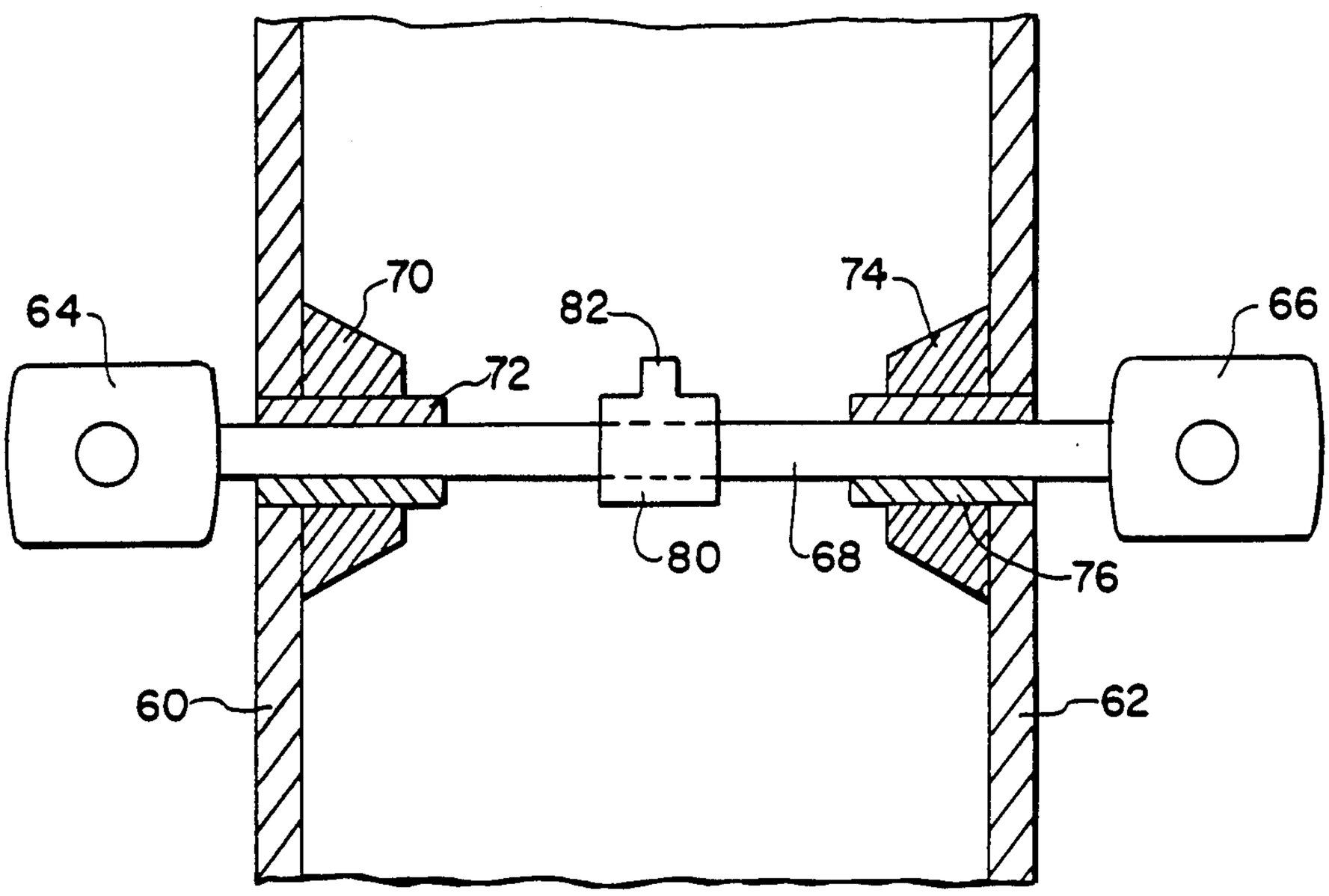


FIG. 3

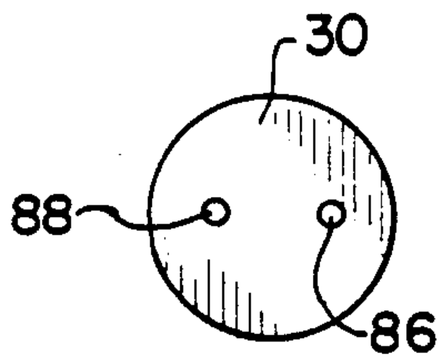


FIG. 4

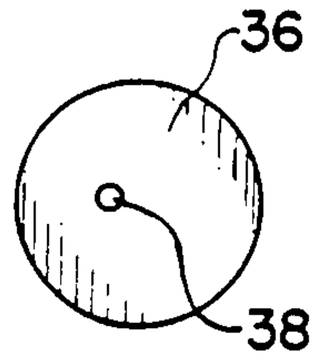


FIG. 5

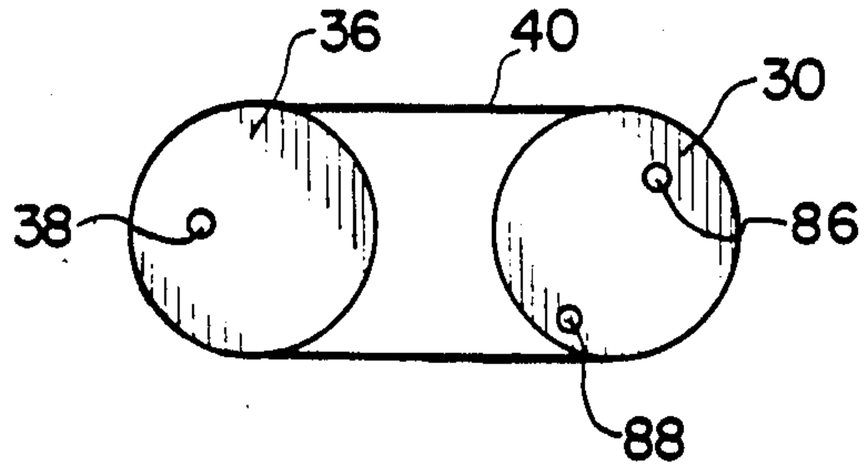


FIG. 6

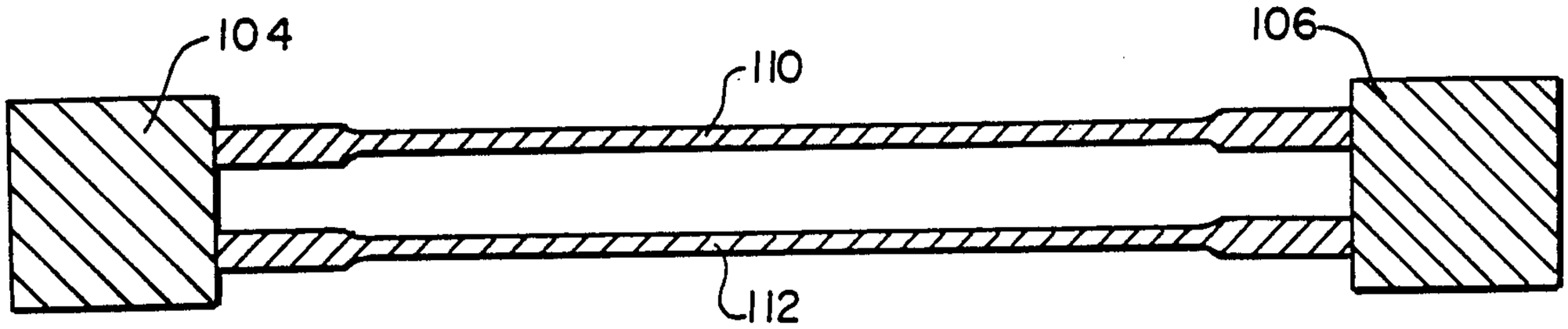


FIG. 7

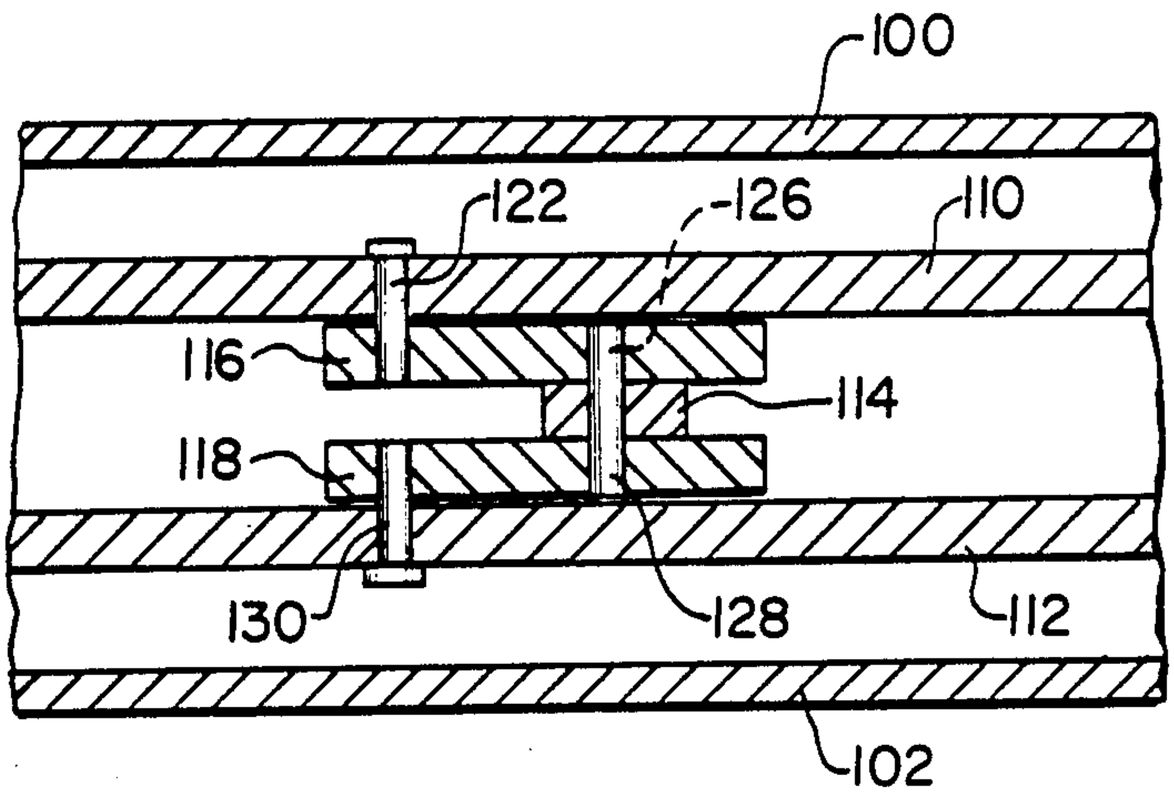


FIG. 8

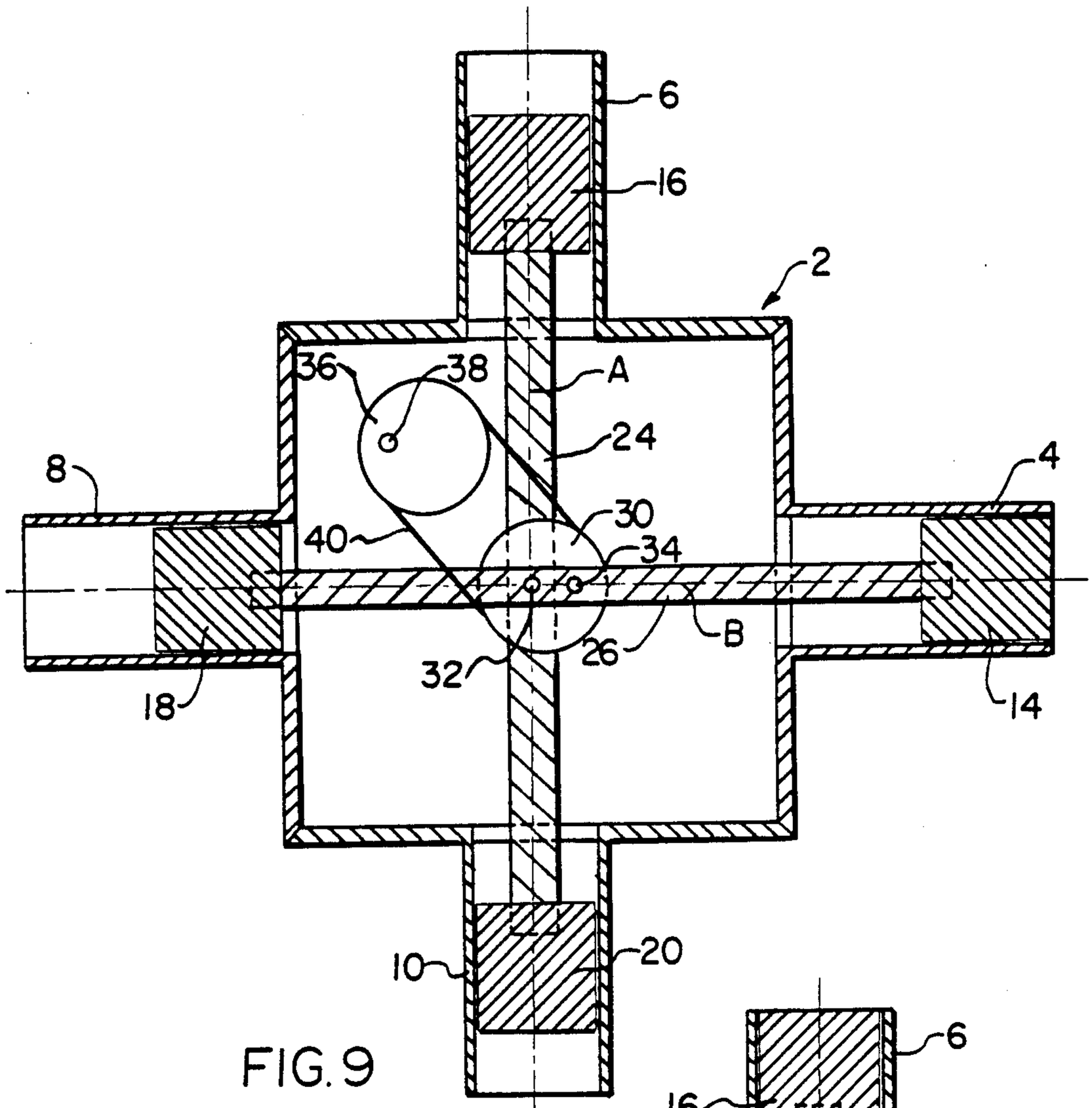

6
16
2
36
38
A
24
8
4
30
40
34
B
26
32
18
14
10
20

FIG. 9

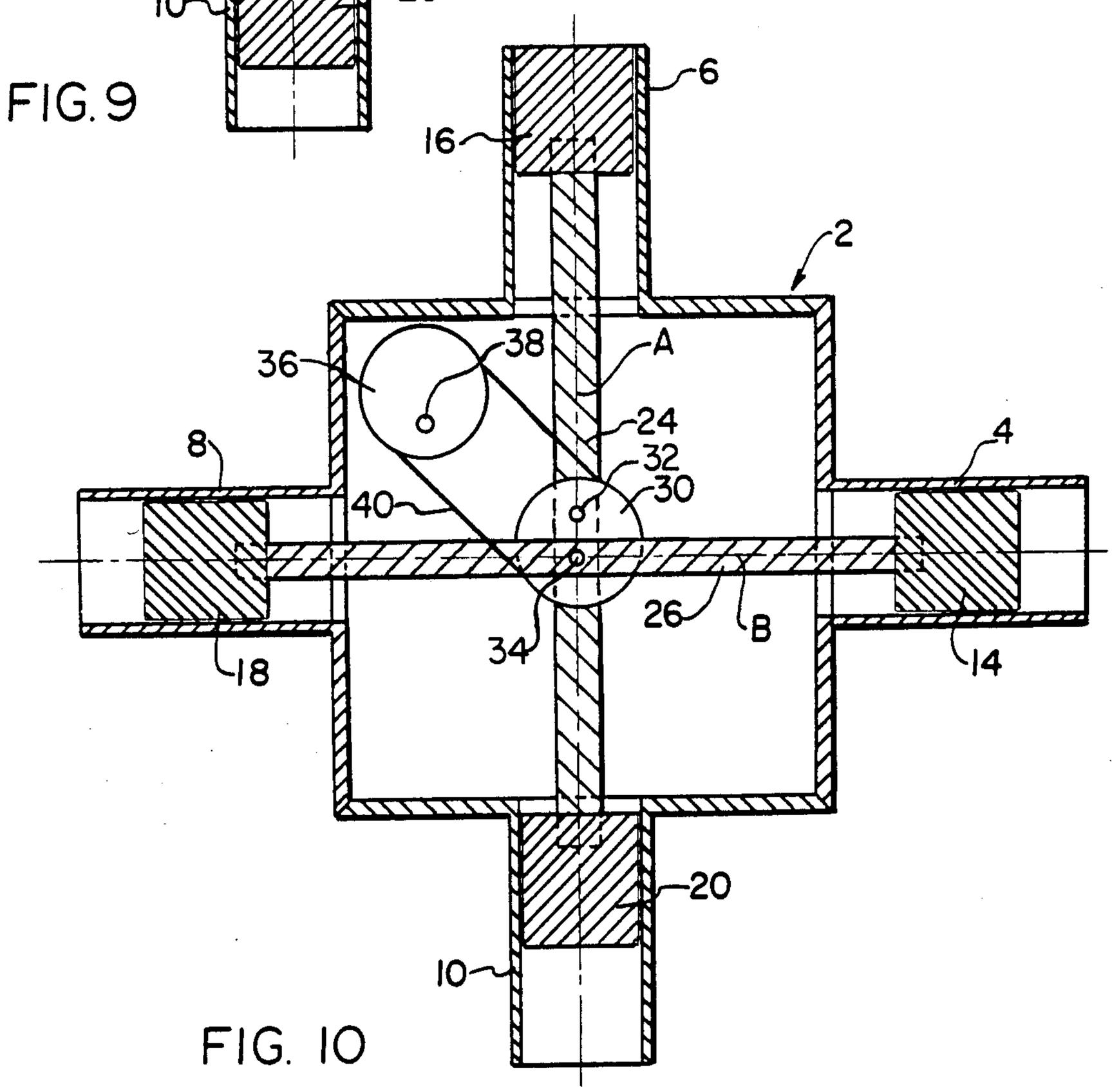

6
16
2
36
38
A
24
8
4
32
30
40
26
B
34
18
14
20
10

FIG. 10

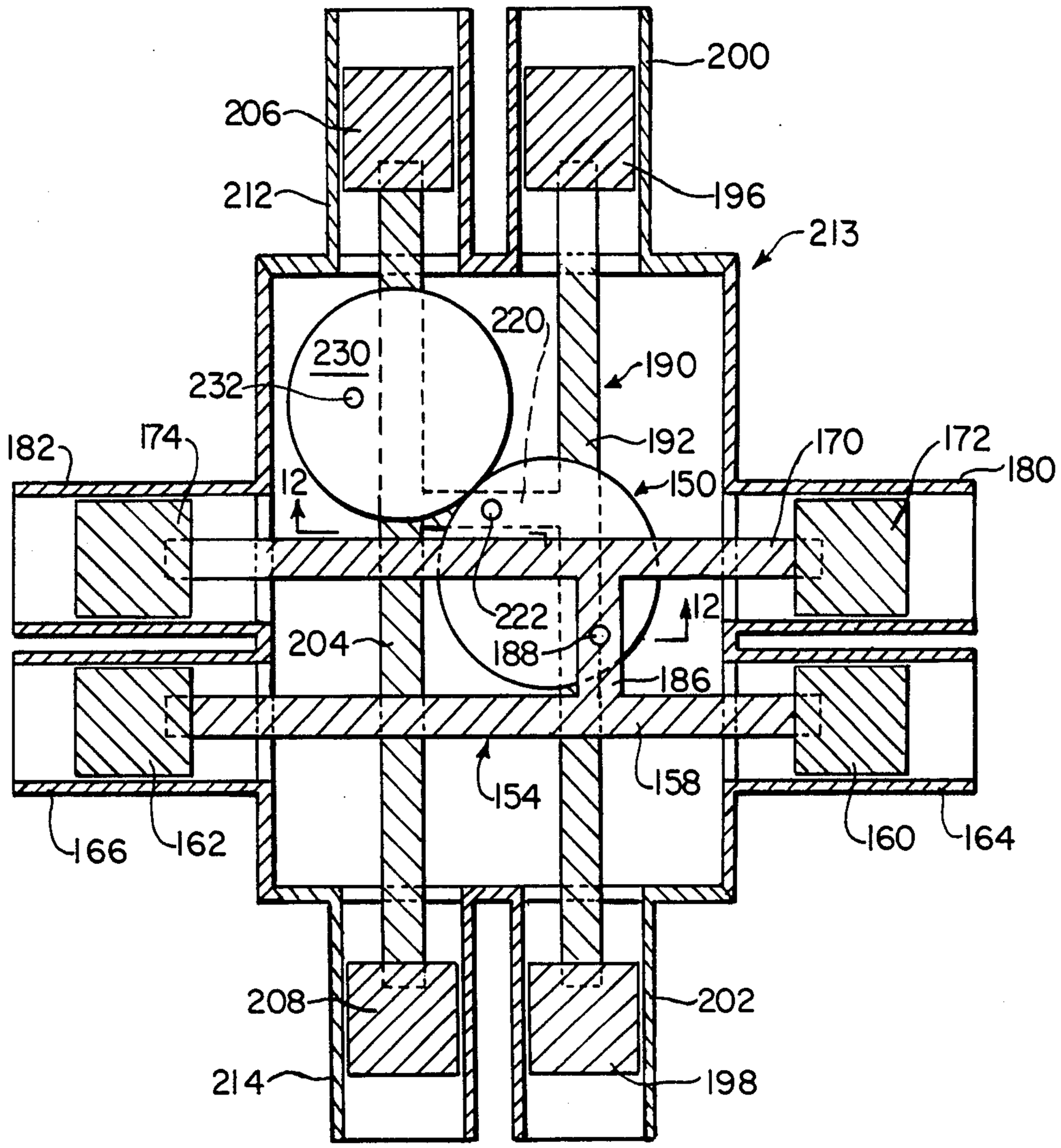

200
206
212
196
213
220
230
232
190
192
174
182
170
172
180
12
150
222
204
188
186
154
158
166
162
160
164
208
202
214
198

FIG. 11

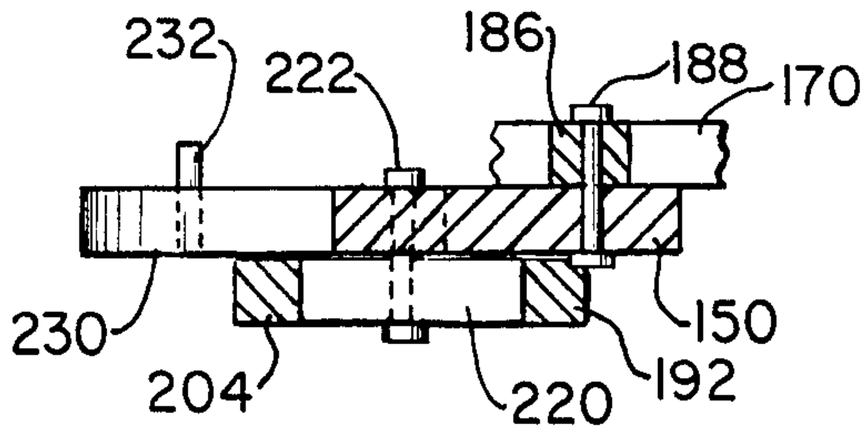

232
222
186
188
170
230
204
220
192
150

FIG. 12

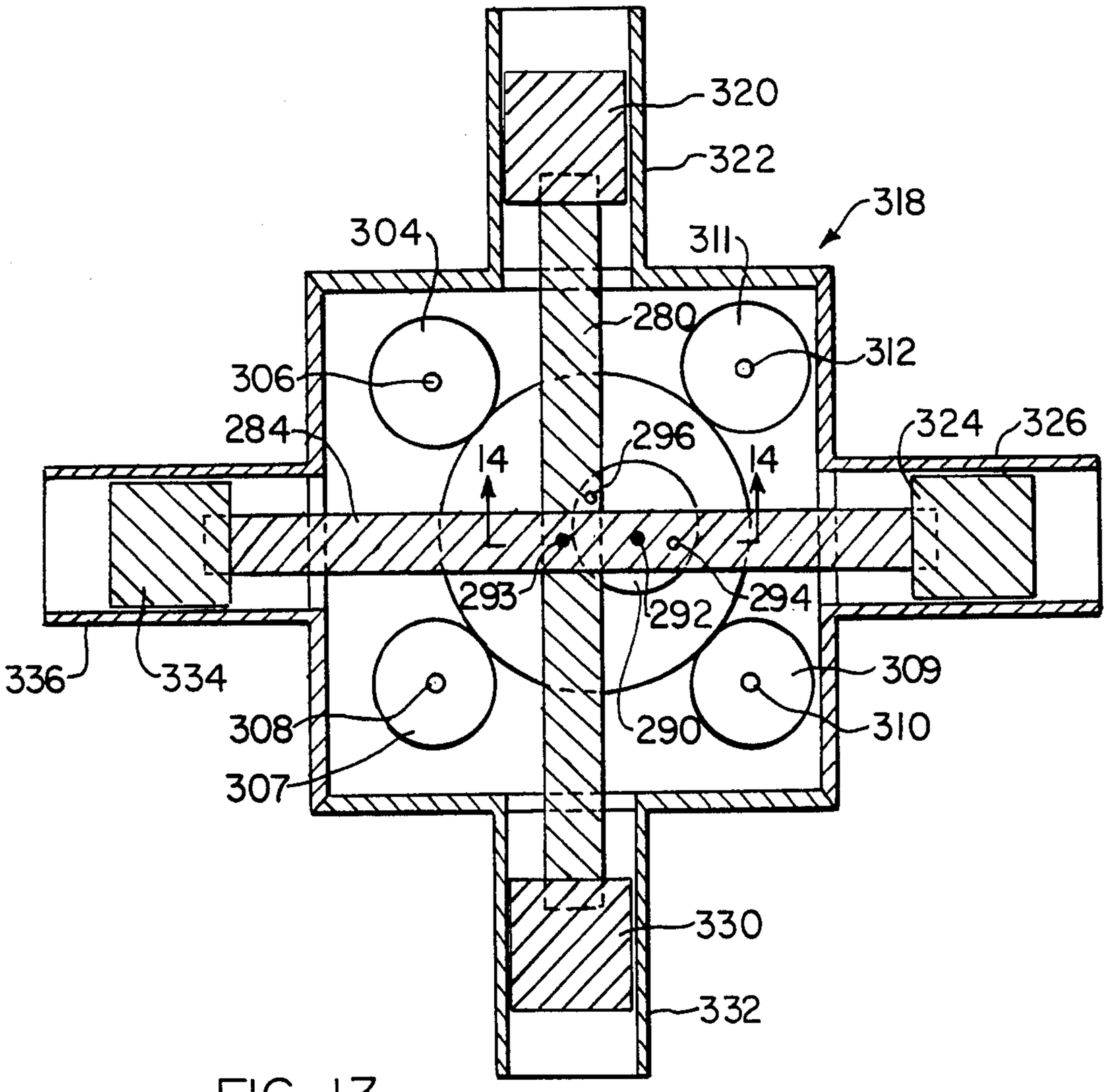

320
322
318
304
311
280
312
306
284
296
14
14
324
326
293
292
294
336
334
309
308
290
310
307
330
332

FIG. 13

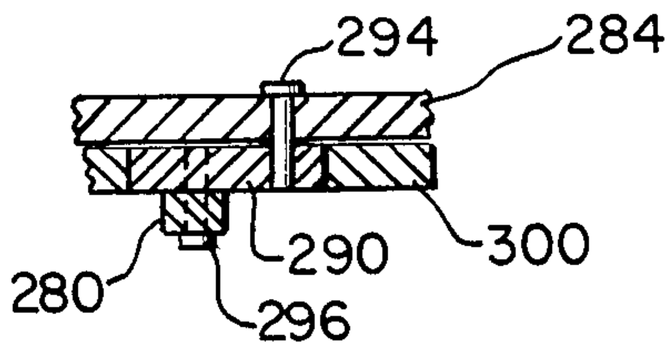

294
284
290
300
280
296

FIG. 14

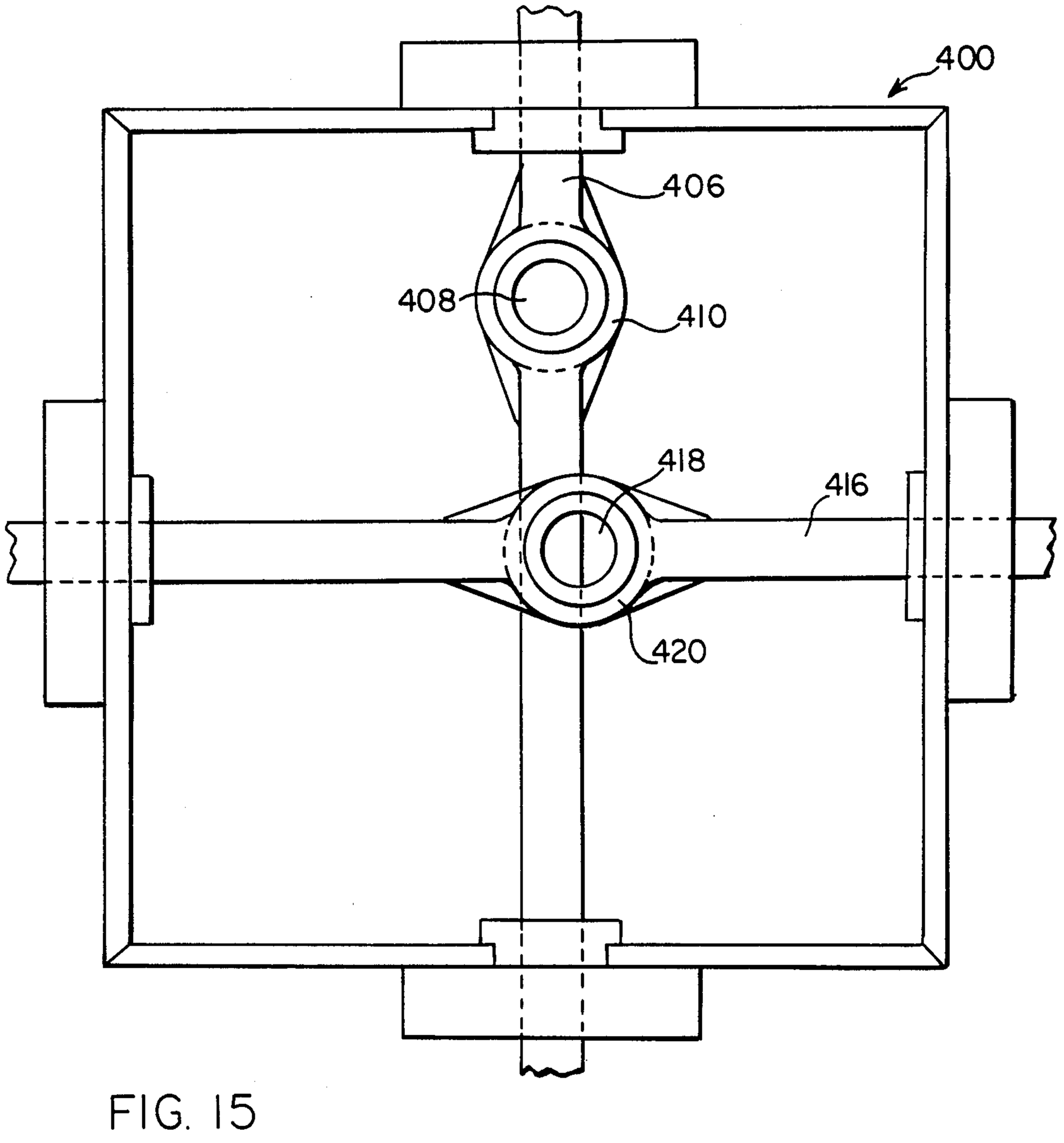


FIG. 15

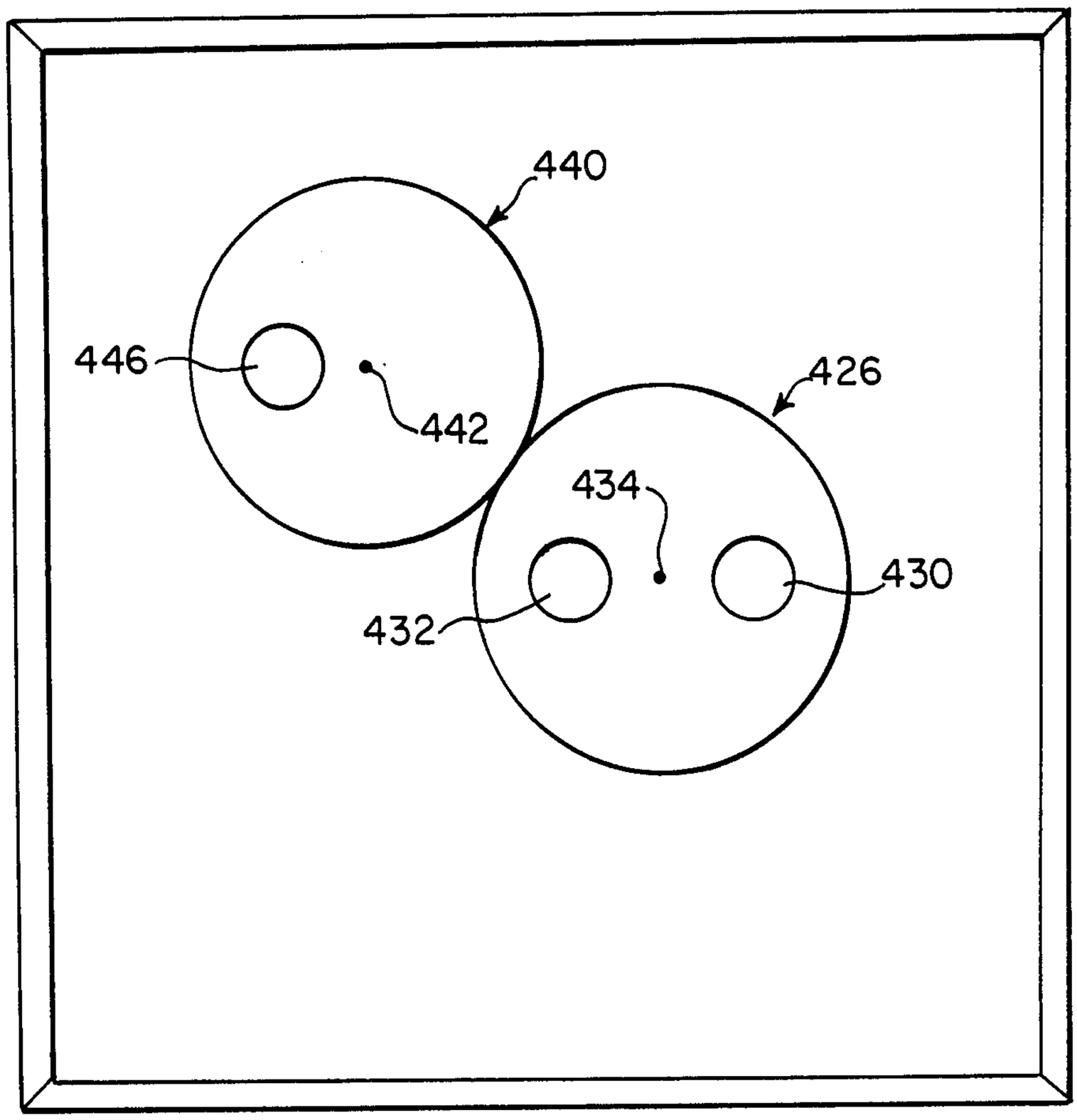


FIG. 16

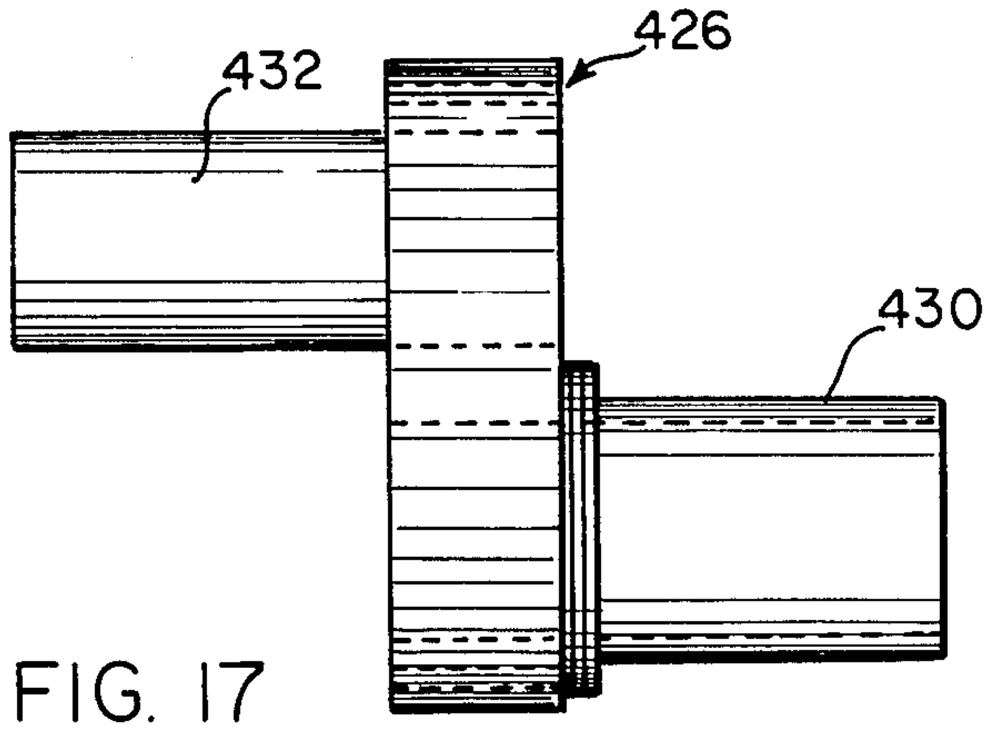


FIG. 17

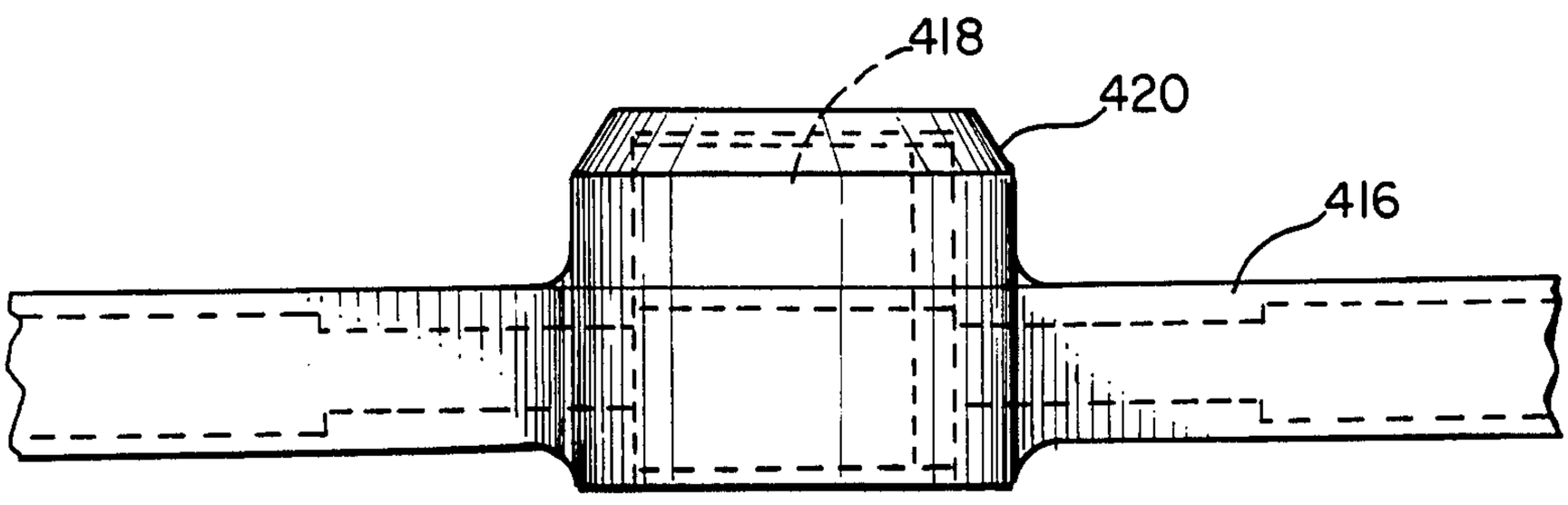


FIG. 18

OSCILLATORY MOTION APPARATUS

CROSS REFERENCE TO RELATED APPLICATION

This Application is a continuation-in-part of U.S. application Ser. No. 628,248, filed July 6, 1984, now abandoned, entitled "OSCILLATORY MOTION APPARATUS."

BACKGROUND OF THE INVENTION 1. Field of the Invention

The present invention relates to an oscillatory motion device having pairs of opposed end members connected by rigid connecting rods and employing trammel means. 2. Description of the Prior Art

The advantageous use of engines of various types including four cycle internal combustion engines for automobiles, trucks, boats, airplanes and in various types of equipment has long been known. The use of two-cycle internal combustion engines in lawn mowers, snow blowers, motorcycles and other uses has long been known.

The Scotch Yoke and elliptical trammel are known means of converting oscillatory motion of a first member into responsive oscillatory motion of a second member.

U.S. Pat. No. 3,583,155 discloses an engine having a free piston cooperating with a driven piston through an elongated gas passageway. U.S. Pat. No. 3,786,790 discloses an internal combustion engine having a pair of pistons connected for common synchronized reciprocating motion.

U.S. Pat. No. 2,807,249 discloses a two stroke, two cylinder, linear opposed engine which employs a standard type of crank, and belt transmission means.

U.S. Pat. No. 1,287,797 discloses an internal combustion engine having pairs of opposed pistons.

French Pat. No. 996,687 discloses an opposed piston internal combustion engine which employs a counterweighted planetary gear mechanism and non-articulating connecting rods.

U.S. Pat. No. 4,485,768 discloses an engine which employs a Scotch yoke and has means for altering the orbit of a slider to change the piston stroke and compression ratio of the engine.

U.S. Pat. No. 2,137,730 discloses opposed piston engines employing a crank disk.

In spite of the numerous varieties of motion converting apparatus and engines in current use and the additional disclosures of other types of motion converting devices, there remains a need for improved oscillatory motion apparatus.

BRIEF DESCRIPTION OF THE INVENTION

The present invention has met the above-described need. The oscillatory motion apparatus has a first reciprocating rod preferably oriented generally perpendicularly with respect to a second rod. A first trammel gear is pivotally secured to the first and second rods. Reciprocation of the rods produces responsive rotation and translation of the trammel gear. An output gear may be rotated responsive to rotation and translation of the trammel gear.

In use in an engine, two pairs of generally opposed cylinders are provided with pistons which reciprocate therein. Each pair of pistons is connected by at least one non-articulating rigid connecting rod which is preferably oriented generally perpendicularly with respect to the rigid connecting rod connecting the other pair of pistons. Trammel means, which preferably take the form of elliptical trammel means, preferably have connections through the center lines of each connecting rod. This results in reciprocation of the pistons establishing translational and counterrotational motion of the trammel linkage. Output means are operatively associated with the trammel linkage and adapted to provide rotary output responsive to rotation and translation of the trammel linkage.

In the engine embodiment, the cyclic sidewall forces produced by the combustion processes in standard engines by a rotating crank mechanism are in the present invention reacted by engine block mounted bearings which reduce cylinder and ring wear.

In one embodiment, a pair of rigid connecting rods connects a pair of pistons with each connecting rod having a separate trammel connected to it and connected to the other connecting rod which is secured to the other pair of pistons. This permits takeoff through two or more separate output members.

It is an object of the present invention to provide improved oscillatory motion apparatus which is capable of motion conversion to provide usable output.

It is another object of the present invention to provide an engine employing such oscillatory motion apparatus.

It is an object of the present invention to provide an improved, lightweight, dependable internal combustion engine.

It is another object of the present invention to provide such an internal combustion engine which has reduced wear of contact surfaces and improved durability.

It is another object of the present invention to provide moving parts for the engine so positioned as to effect cancellation of forces to minimize vibrations and also permitting use of a lighter engine block and crankcase.

It is another object of the present invention to provide such an internal combustion engine which has a minimum number of moving parts, improved efficiency, a high horsepower to weight ratio and one which may have a generally flat profile which permits use in a smaller engine compartment.

These and other objects of the invention will be more fully understood from the following description of the invention and reference to the illustrations appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic cross-sectional illustration of a form of apparatus of the present invention.

FIG. **2** is a cross-sectional illustration showing a portion of the apparatus of FIG. **1**.

FIG. **3** is a cross-sectional illustration showing a portion of the apparatus of the present invention.

FIG. **4** is a top plan view of a trammel gear of the present invention.

FIG. **5** is a top plan view of a form of output gear member of the present invention.

FIG. **6** is a top plan view of a form of trammel gear and output gear member subassembly of the present invention.

FIG. **7** is a cross-sectional illustration of a modified form of connecting rod of the present invention.

FIG. 8 is a cross-sectional illustration of a modified form of connecting linkage of the present invention.

FIG. 9 is a schematic cross-sectional illustration of the apparatus of FIG. 1 with the pistons in a different position.

FIG. 10 is a schematic cross-sectional illustration of the apparatus of FIGS. 1 and 9 with the pistons in a different position.

FIG. 11 is a schematic cross-sectional illustration of a modified form of the invention.

FIG. 12 is a cross-sectional illustration of the embodiment of FIG. 11 taken through 12—12.

FIG. 13 is a schematic view of another embodiment of the invention.

FIG. 14 is a cross-sectional illustration of the assembly of FIG. 13 taken through 14—14.

FIG. 15 is a schematic cross-sectional illustration of a further embodiment of the inventions.

FIG. 16 is a schematic cross-sectional illustration of a trammel gear and output gear of the embodiment of FIG. 15.

FIG. 17 is an elevational view a portion of the embodiment of FIG. 15.

FIG. 18 is a fragmentary elevational view of a portion of the yoke of the embodiment of FIG. 15.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

While it will be appreciated that the present invention may be employed advantageously in many types of apparatus wherein two members crossing each other have coordinated oscillatory motion, the invention will be described herein with reference to one of the presently preferred uses, i.e., in connection with engines. While the engine may be of any desired type such as for example, steam, pneumatic or hydraulic engines, an internal combustion engine will be described. In connection with embodiments of the invention other than engines, it will be appreciated that elements other than pistons may be secured to the rods. As such elements will not alter the mechanical action of the invention, they will be referred to herein generically as "pistons" even though they may not function as such in a technical sense.

The present invention contemplates a first member being rotated by the oscillating linkage members as will be described hereinafter and a second output member being rotated responsive to rotation of the first member. The first and second members may be of any form suitable for effecting suitable transmission of the rotational movement. The members may be gears which are directly intermeshed directly or indirectly or connected by toothed belts, for example. They may be pulleys or sprockets connected by a suitable belt or chain or any other suitable means. For convenience of reference herein all such members will be referred to generically as "gears" regardless of whether the members have teeth and regardless of whether they are shaped like gears. It will be appreciated that the gears function both as a linkage to connect the connecting rods and as rotary output source.

Referring to FIG. 1, there is shown an internal combustion engine having an engine block/crankcase 2 which in the form illustrated is substantially rectangular. While a square engine block/crankcase 2 is preferred any shape which permits crossing of the connecting rods and the desired freedom of movement may be employed. A pair of generally rectangular side plates (not shown) may be secured to the rectangular frame to provide for a closed block of generally rectangular configuration. Other configurations may be employed depending upon accessories and complimentary components which might be used with the engine for a particular installation.

Four cylinders 4, 6, 8, 10 project outwardly from the engine block/crankcase 2 and contain, respectively, reciprocating pistons 14, 16, 18, 20. It will be appreciated that pistons 16, 20 are generally aligned and are connected to each other by substantially rigid connecting rod 24 which has a central axis A. Similarly, pistons 14, 18 are generally aligned and are connected by a substantially rigid piston rod 26 which has a central axis B. It will be appreciated that axis A is substantially perpendicular to axis B. Trammel gear 30 is pivotally connected to connecting rod 24 through pivot pin 32 which preferably is disposed on or closely adjacent to central axis A. (For convenience of illustration, the gear teeth will not be shown herein.) Trammel gear 30 is connected to connecting rod 26 through pivot pin 34 and is preferably disposed on axis B. It is preferred that the pin spacing between pins 32, 34 (measured from center to center) be about one-half the length of the piston stroke.

As the engine of the present invention is adapted to function in a two cycle or four cycle engine using a wide variety of fuels, details regarding fuel choice and introduction, combustion and where appropriate valve arrangements and sequence of operations will be readily apparent to those skilled in the art, a detailed disclosure of the same will not be provided herein. It will be appreciated that as the combustible fuel mixture is ignited in each cylinder, that cylinder's piston will be caused to move toward the trammel gear 30. By movement of the various pistons in a predetermined sequence (clockwise or counterclockwise) trammel gear 30 will be caused to rotate and thereby convert the translational movement of connecting rods 24, 26 into responsive rotary and translatory movement of the trammel gear 30.

In a preferred embodiment of the invention, a rotably mounted output gear 36 (shown without teeth) has an output shaft 38 which is eccentrically positioned thereon supported for axial rotation by suitable bearings (not shown). Output gear 36 is connected to the trammel gear 30 by a toothed endless belt 40. In the form shown, output shaft 38 is generally parallel to and axially offset from trammel pivot pins 32, 34. As a result of the positioning and configuration of the trammel gear 30 and output gear 36, the output shaft 38 will be subjected to rotational movement about its axis responsive to rotation of the trammel gear 30. Output shaft 38, is eccentrically mounted on gear 36 to compound the motion of the trammel gear. In one embodiment of the invention, the periphery of the trammel gear 36 and output gear 36 will have gear teeth and the belt (40) will be an endless toothed belt (40). In another embodiment of the invention, the periphery of the trammel gear 30 and output gear 36 may be grooved to create a pulley effect which cooperates with an endless belt. Other transmission means such as chains operatively associated. with a sprocket type trammel gear may be employed.

Referring to FIG. 2, there is shown a crosssectional view providing details of the assembly. The side plates 50, 52 are walls of the engine block/crankcase 2. Trammel gear 30 which is generally disk-shaped, is connected to connecting rod 26 by pivot pin 34. The tram-

mel gear **30** is also connected to connecting rod **24** by means of pivot pin **32**. The pivot pins **32, 34** as well as the preferred placement thereof on or closely adjacent to the longitudinal axis A, B, cooperate to convert the reciprocating translational movement of connecting rods **24, 26** into rotary movement of the trammel gear **30**.

FIG. **3** shows further details of the manner in which the connecting rod may be assembled to cooperate with the opposed pistons. In this embodiment, the engine block has walls **60, 62**. Pistons **64, 66** are secured to opposed ends of substantially rigid connecting rod **68**. A pillow block **70** supports a linear bearing **72** which passes through engine block/crankcase wall **60**. Similarly, pillow block **74** supports linear bearing **76** which passes through engine block wall **62**. The linear bearing facilitates reciprocation of the connecting rod **68** responsive to movement of pistons **64, 66** thereby minimizing wear, within the cylinder.

A bearing pin **80** has a projection **82** which is adapted to be received within an opening in the trammel gear (not shown). The bearing pin **80** may be fixedly secured to the connecting rod **68** by means of a suitable mechanical fastener such as a split ring clamp, for example.

As is shown in FIG. **4**, the trammel gear (shown without teeth) in the form shown has a generally circular configuration. In the form shown, it has a pair of relatively spaced openings **86, 88** which are adapted to receive the pivot pins. If desired, neither of the openings **86, 88** need pass through the center of trammel gear **30**. For example, they might be positioned equidistant from the center on opposite sides thereof. If desired, the trammel gear may have a non-circular configuration. FIG. **5** shows generally the circular output gear **36** which has a projecting shaft **38**. If desired, gear **36** may have a non-circular configuration.

As is shown in FIG. **6**, the trammel gear **30** and output gear **36** are connected by toothed endless belt **40** such that rotational movement of the trammel gear **30** responsive to reciprocation of the pistons will effect responsive rotation of the output gear **36**.

It will be appreciated that the oscillatory motion apparatus of the present invention provides numerous benefits not obtained with prior art constructions. First of all, it has very few moving parts and thus will be economical to manufacture and maintain and will be durable. Further contributing to durability in use in engines is the fact that unlike conventional internal combustion engines wherein the crank-connecting rod assembly driving the pistons are articulating thereby providing uneven cyclic forces to the cylinder walls and piston, the present invention involves pure reciprocation which does not present such uneven unloading. The engine will have a high horsepower to weight ratio, preferably in excess of 1. The engine may be made with a very low profile and may be employed in two cycle as well as four cycle environments. Also, vibrating will be reduced as a result of the offsetting forces of the moving parts cancelling each other.

Referring to FIGS. **7** and **8**, a further embodiment of the invention will be considered. Whereas in the embodiment described hereinbefore a rigid unitary connecting rod connected each pair of pistons, in the embodiment of FIGS. **7** and **8** a modification is provided. The engine block walls **100, 102** are spaced from the pair of rigid connecting rods **110, 112** which connect pistons **104, 106**. It is preferable that the central portions of the connecting rods be substantially flat, as is true with the first embodiment, in order to facilitate efficient relative movement of the parts. A single rigid connecting bar **114** is oriented generally perpendicularly to connecting rods **110, 112** and connects a pair of pistons (not shown). A pair of trammel gears **116, 118** is provided. Trammel gear **116** is pivotally connected to the axis of connecting rod **114** by pin **126** (shown as being behind pin **128** in this view). This portion of the assembly will function exactly as in the hereinbefore described embodiment. In addition, second trammel gear **118** is pivotally connected to the axis of connecting rod **114** by pin **128** which enters connecting rod **114** at a position spaced from pin **126**. In this fashion as pistons **104, 106** are subjected to reciprocating movement, both trammel gears **116, 118** will be caused to rotate and translate responsively thereto. Output gears such as **36** (FIG. **1**) may be provided independently for each of the trammel gears **116, 118** and preferably are spaced from the trammel gears in opposite directions with respect to each other. As a result, independent rotary output is provided for each of the two trammel gears **116, 118**. If desired, a flywheel (not shown) may be secured to the output shafts in order to enhance efficiency of operation of the engine. The trammel gear and output gear generally will have sufficient weight to make a flywheel unnecessary.

Referring to FIGS. **9** and **10**, the apparatus of FIG. **1** is illustrated, but with the pistons in different positions. In FIG. **1**, piston **18** is shown in its outermost position, piston **14** in innermost position and pistons **16, 20** are in intermediate positions. Piston **18** in FIG. **1** is in the firing stage, piston **20** is in the compression stage and piston **16** is in the exhausting stage.

FIGS. **11** and **12**, show a modified form of the invention employing a single trammel gear **150** in an eight cylinder engine. A first generally H-shaped rigid connecting rod means **154** has a first rod **158** secured to pistons **160, 162** which are positioned respectively within cylinders **164, 166**. Second, rod **170** has pistons **172, 174** secured thereto. Pistons **172, 174** are positioned respectively, within cylinders **180, 182**, and cross-member **186** creates a rigid connection between first rod **158** and second rod **170**. Pin means **188** pivotally connects trammel gear **150** with generally H-shaped connecting rod **154**.

A second generally H-shaped rigid connecting rod means **190** is oriented generally perpendicularly with respect to first connecting rod **154**. Second connecting rod means **190** has third connecting rod **192** to which are attached pistons **196, 198** which are received within cylinders **200, 202**, respectively. Second connecting rod means **190** has fourth connecting rod **204** with pistons **206, 208** secured thereto and disposed in cylinders **212, 214**, respectively. Cross-member **220** connects third connecting rod **192** to fourth connecting rod **204**. Pin means **222** connects cross-member **220** to trammel gear **150**.

As in the other embodiments, oscillating movement of first connecting rod means **154** and second connecting rod means **190** will effect rotation of trammel gear **150**. Trammel gear **150** which has teeth (not shown) meshed with teeth (not shown) on output gear **230** which is fixedly secured to eccentrically positioned output shaft **232**. As a result, rotary output results from oscillation of the connecting rod means.

While the engine block **213** has been shown in FIG. **11** as being generally rectangular it is generally preferable to employ a square block. Any shape which will

permit the desired freedom of movement of engine parts may be employed.

In the position shown in FIG. **11**, all of the pistons are disposed generally in the midpoint of their path of travel. If the engine is a four cycle engine, one piston of a pair would be firing while the other would be exhausting. The sequence of cycles may be any desired such as in the clockwise or counterclockwise directions.

The use of the present invention in an engine provides an environment of constrained linear motion which resists piston slap and excessive cylinder wall shock forces. The forces of combustion and inertia are absorbed and reacted by the linear sidewall bearings which isolate the piston and cylinder walls from the destructive forces generally associated with reciprocating engines. As a result, the combustion chamber components need only resist compressive forces and not tension, compression and bending. Reduction of non-compressive forces allows use of ceramic materials which have limited ability to handle such non-compressive forces, but can handle higher temperatures and have better wear characteristics than other materials such as steel or aluminum.

The piston and connecting rod motion of the present invention employ linear oscillatory motion essentially within a plane. This is to be contrasted with conventional engines which have crank-connecting rod assemblies providing uneven cyclic forces to the cylinder walls and piston. The present invention permits the advantageous use of ceramic materials. Ceramic materials generally cannot be employed efficiently in conventional engines as they have inadequate strength and wearing properties. The present invention permits advantageous use of cylinders which are made of ceramics or have ceramic linings which may take the form, for example, of a ceramic sleeve or coating. This lining may be employed in combination with a steel cylinder. Such use of ceramics would tend to reduce engine vibrations, reduce wear, reduce undesired loss of ring pressure and permit the engine to operate at higher temperatures to reduce undesired oxide emissions. The pistons, heads and valves may also be made of ceramics.

A wide variety of ceramic materials may be employed successfully in the present invention. Among the specific materials presently believed to be suitable are materials selected from the group consisting of silicon nitride and silicon carbide. Another suitable material is that sold under the trade designation Syalon.

The pistons shown in FIG. **1** generally, depending upon output requirements, be fired in a clockwise sequence (**14**, **20**, **18**, **16**) or a counter-clockwise sequence (**14**, **16**, **18**, **20**).

In FIG. **9**, for this two cycle configuration piston **14** is in the firing stage, piston **16** is in the compression stage and piston **20** is in the exhausting stage. Similarly, in FIG. **10**, piston **16** is in the firing stage, piston **18** is in the compressing stage and piston **14** is in the exhausting stage.

Referring to FIGS. **13** and **14** there is shown a modified form of the invention. In this embodiment a first rigid connecting rod **280** is disposed within an engine block **318** and has a pair of pistons **320**, **330** secured to opposed ends thereof which pistons oscillate within cylinders **322**, **332** respectively. Second rigid connecting rod **284** has pistons **324**, **334** secured thereto. Pistons **324**, **334** oscillate respectively within cylinders **326**, **336**. Trammel gear **290** is pivotally secured to connecting rod **280** by pin means **296** and to connecting rod **284** by pin means **294**. Oscillation of connecting rods **280**, **284** will effect rotation of trammel gear **290** which has its center **292** spaced from the point **293** of axial intersection of connecting rods **280**, **284**. Trammel gear **290** preferably has a journaled bearing surface (not shown) which contracts the inner surface of ring gear **300** which has an opening which receives trammel gear **290**. External gear teeth on ring gear **300** will mesh with external gear teeth on output gears, **304**, **307**, **309**, **311** which fixedly are respectively secured to centrally positioned output shafts **306**, **308**, **310**, **312**. In this manner, rotation of trammel gear **290** effects responsive rotation of output shafts **306**, **308**, **310**, **312** through gears **300**, **304**, **307**, **309**, **311**.

It will be appreciated that while four output gears **304**, **307**, **309**, **311** have been shown associated with said ring gear **300** in planetary fashion other numbers of such output gears may be employed if desired.

Referring to FIGS. **15** through **18** a preferred type of trammel gear of the invention will be considered. As is shown in FIG. **15**, a block **400** which may be of the type shown in FIG. **1** will have suitable cylinders and pistons (not shown). First connecting rod **406** has a yoke **410** which has opening **408**. Second connecting rod **416** is oriented generally perpendicular to first connecting rod **406** and has yoke **420** which defines opening **418**. Coordinated oscillation of the connecting rods **410**, **420** will produce oscillation of openings **408**, **418**. (A detail of yoke **420** which may be identical with yoke **410** is shown in FIG. **18**.)

As is shown in FIGS. **16** and **17** trammel gear **426** has a center **434** and a pair of projecting shafts **430**, **432** which are secured thereto and project in opposite directions. In the form shown shafts **430**, **432** have their centers spaced from center **434**. Each shaft **430**, **432** is rotatably received within a yoke opening **408**, **418** preferably with a suitable interposed bearing (not shown). It will be appreciated that by providing yokes **410**, **420** in the appropriate relative positions, oscillation of connecting rods **406**, **416** will through yokes **410**, **420** and shafts **430**, **432** effect responsive rotation of trammel gear **426**. Output gear **440**, has a center **442** and is secured to output shaft **446**. It has teeth (not shown) intermeshed with teeth (not shown) of trammel gear **426**. Rotation of output gear **440** will effect axial rotation of output shaft **446**.

It will be appreciated, therefore, that the present invention provides a compact, high efficiency, durable, easy to maintain oscillatory motion apparatus. When employed in an engine, it has a high horsepower to weight ratio. The apparatus converts linear oscillatory motion which may be considered to be within a plane to rotational motion.

While the oscillatory motion apparatus of the present invention may be employed for numerous purposes and when employed in the engine environment may take many forms, an example of certain parameters in the engine environment may be helpful with reference to FIG. **1**, the engine block or crankcase **2** may have a depth of about 6 to 7 inches and length and width of about 6 to 12 inches. The length and width are preferably equal. The overall size of the engine block **2** and cylinder projections may be about 6 to 7 inches deep and about 18 to 26 inches in length and width. The engine and support equipment may weigh about 80 to 150 pounds. The horsepower to weight ratio may be about 1 to 4 without augmented combustion processes.

While, for convenience of reference, the disclosure has focused upon use of the apparatus to convert oscillatory motion to rotary motion, it may be employed in a reverse manner to convert rotary input into oscillatory output such as might be employed in a pump, for example.

While for simplicity of disclosure specific reference has been made herein to embodiments of the invention employed in engines, the invention is usable in many additional devices such as pumps on apparatus wherein such motion may be advantageously employed.

While, for convenience of reference, the use of pins in effecting certain connections between members has been described, it will be appreciated that other means of effecting secure mechanical joinder while permitting the desired freedom of movement will be apparent to those skilled in the art and may be used. A bearing yoke, for example, may be employed.

While the rigid connecting rods shown herein are generally straight, it will be appreciated that if desired in order to save space or for other reasons, they may be created with a generally U-shaped offset within which the trammel gear may be received. The offset would be so sized as to permit the desired oscillatory movement.

While the trammel gear disclosed herein has been illustrated as being circular, it will be appreciated that it may be elliptical, egg-shaped, nautilus shaped or provided in any other functionally effective form such as a translating crank, for example.

While the apparatus of the present invention has been shown as having two sets of connecting rods connected to the trammel gear if desired, additional connecting rods angularly offset from the others may be secured to the trammel gear.

Whereas particular embodiments of the invention have been described above for purposes of illustration, it will be appreciated by those skilled in the art that numerous variations of the details may be made without departing from the invention as described in the appended claims.

We claim:

1. Oscillatory motion apparatus comprising

first rod means mounted for oscillating movement in a first direction,

second rod means mounted for oscillating movement in a second direction,

first trammel gear means pivotally secured to said first rod means by first pivot means,

said first trammel gear means pivotally secured to said second row means by second pivot means, whereby coordinated oscillating movement of said first rod means and said second rod means will effect responsive rotational and translational movement of said trammel gear means,

said first pivot means being relatively spaced from said second pivot means, p**1** eccentrically mounted output gear means having an axially fixed mounting, operatively associated with said trammel gear means for effecting rotational movement responsive to rotation and translation of said trammel gear means, and

said output gear means having an output gear and a rotatable output shaft positioned coaxially with the eccentric mounting of said output gear, whereby the rotational component of the movement of said trammel gear means will effect rotation of said output shaft.

2. The oscillatory motion apparatus of claim **1** including said apparatus being an engine.

3. The oscillatory motion apparatus of claim **2**, including

an engine block,

first and third cylinders generally aligned on a first axis,

second and fourth cylinders generally aligned on a second axis,

said second axis being oriented substantially perpendicular with respect to said first axis,

first and third pistons disposed respectively within said first and third cylinders and adapted for reciprocating movement therein,

said rod means having substantially rigid first and second connecting rod means,

said first substantially rigid connecting rod means fixedly secured to said first and third pistons,

second and fourth pistons disposed respectively within said second and fourth cylinders,

said second substantially rigid connecting rod means oriented generally perpendicularly with respect to said first connecting rod means, and

said second connecting rod means being fixedly secured to said second and fourth pistons.

4. The engine of claim **3** including

said cylinders being composed at least in part of a ceramic material.

5. The engine of claim **4** including

said cylinders having a ceramic lining.

6. The engine of claim **5** including

said ceramic material being selected from the group consisting of silicon nitrideand silicon carbide.

7. The engine of claim **3** including

first pivot means connecting said first trammel gear means with said first connecting rod means, and

second pivot means connecting said first trammel gear means with said second connecting rod means.

8. The engine of claim **7** including

said first pivot means being spaced from said second pivot means by a distance generally equal to one-half the stroke of a said piston.

9. The engine of claim **7** including

said output shaft eccentrically positioned with respect to said output gear, and

said rotatable output shaft being generally parallel to and axially offset from said first and second pivot means.

10. The engine of claim **9** including

said first and second pivot means including pivot pins.

11. The engine of claim **10** including

said first pivot means passing generally through the central axis of said first connectwng rod means, and

said second pivot means passing generally through the central axis of said second connecting rod means.

12. The engine of claim **10** including

said engine being an internal combustion engine.

13. The engine of claim **10** including

endless belt means connecting said trammel gear means to said output gear means.

14. The engine of claim **13** including

said trammel gear means being a trammel gear having teeth and said output gear means being an output gear having teeth.

15. The engine of claim **14** including

endless cogged belt means connecting said trammel gear with said output gear.

* * * * *